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Corrosion evaluation by electrochemical techniques of the liner structure in nuclear power plants: A case study

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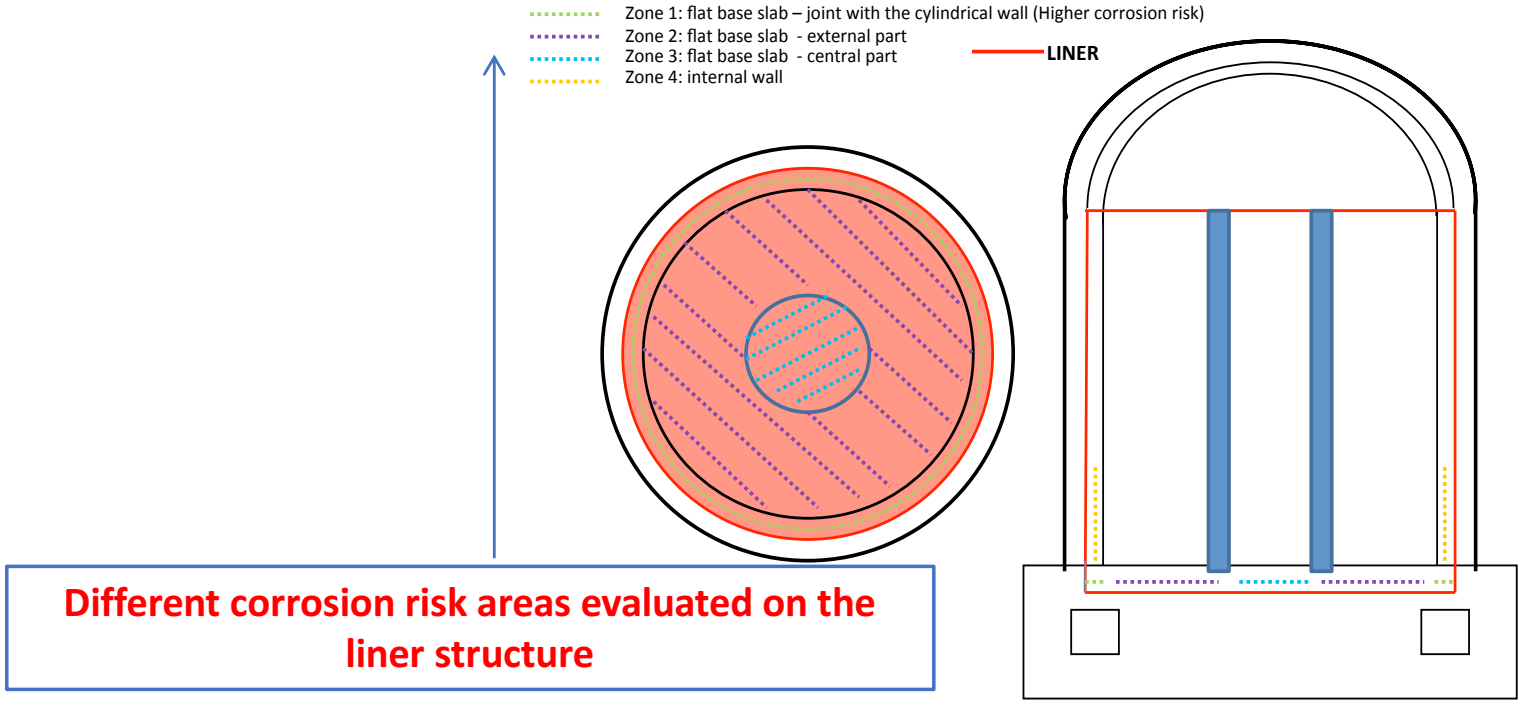
Introduction

- The liner structure in Nuclear Power Plants provides containment for the operation and therefore the study of its durability and integrity during its service life is an important issue.
- There are several -causes for the deterioration of the liner, which in general involve corrosion due to its metallic nature.
- Present paper is aimed at describing the assessment of corrosion problems of two liners from two different nuclear power plants, which were evaluated using non-destructive electrochemical techniques

Liner Structure

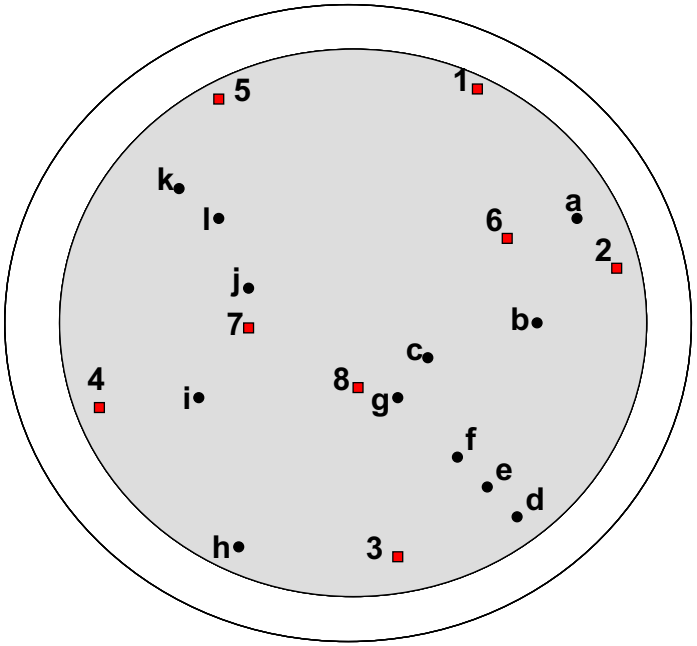
Concrete containments are metal lined, reinforced concrete pressure-retaining structures that in some cases may be post-tensioned. The concrete vessel includes the concrete shell and shell components, shell metallic liners, and penetration liners that extend the containment liner through the surrounding shell concrete



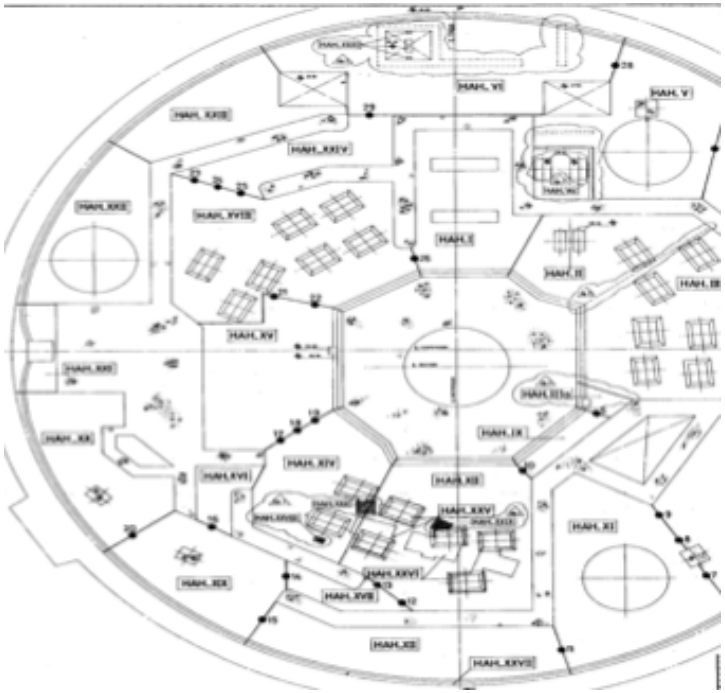
Different corrosion risk areas evaluated on the liner structure

Experimental

- A LINER was studied during more than 10 years by non destructive electrochemical Measurements were made directly over the concrete slab.

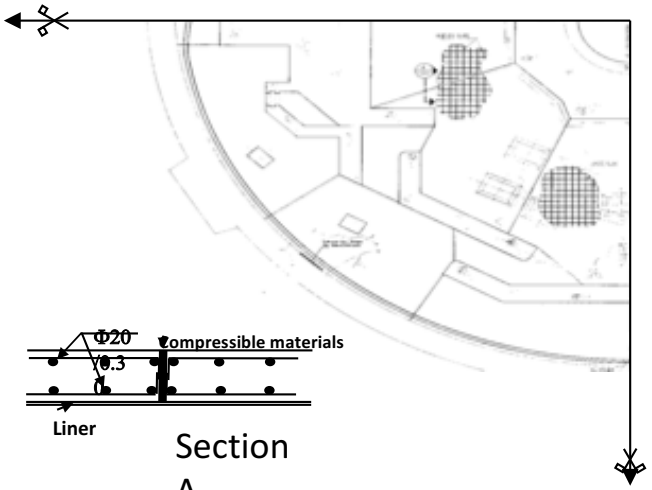


LINER A



Experimental

- The protection concrete has 2 carbon steel meshes embedded in both sides of the slab. The rebar diameter is 20 mm and the grid size is 30 cm.
- The concrete thickness varies along the slab, being constant at the lower surface, where the liner is attached, and variable at the upper one, depending on the structure necessities. The total slab thickness goes from 0.50m to 0.80 m. There are 10 mm-thick compressible materials and seals, with seismic properties, in all the joints between the slab and the perimetral walls.



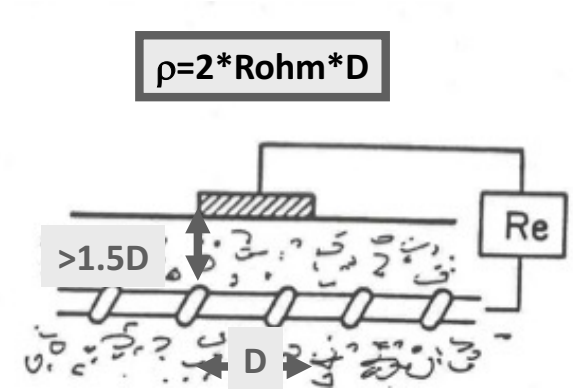
Section A

Corrosion rate quantification:

Stern Geary equation

$I_{corr} = B/A.R_p$

RESISTIVITY MEASUREMENT: Galvanostatic Pulse (Disc method)



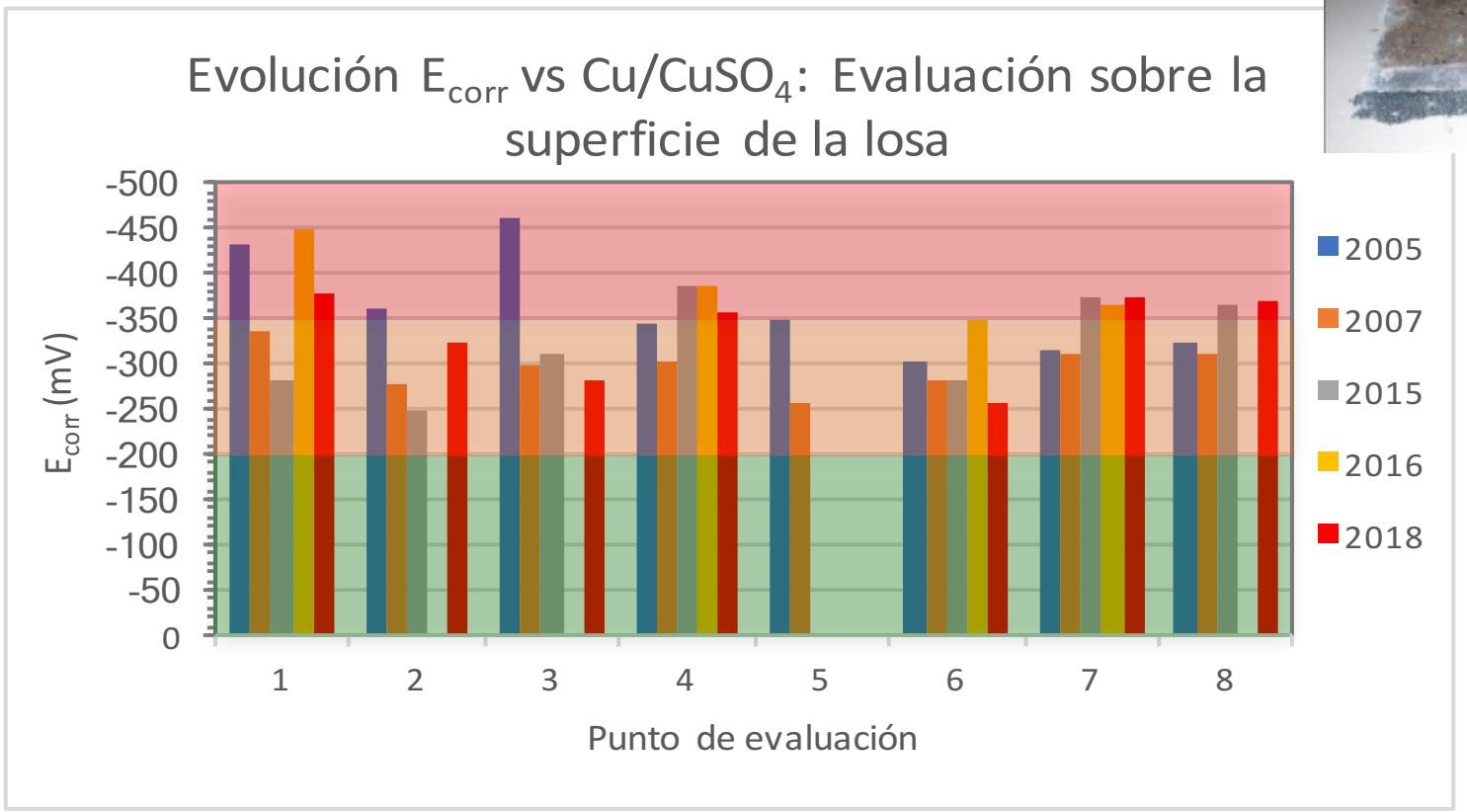
CORROSION POTENTIAL MEASUREMENT: Mn/MnO Ref. Electrodes

CRITERIO Ecorr (ASTM C-876) CUALITATIVO			CRITERIO ρ CUALITATIVO			CRITERIO Icorr CUANTITATIVO		
	Si E_{corr}>-200mV	Prob corr <10%		>100 KΩcm	DESPRECIABLE		I_{corr}<0.1µA/cm^2	DESPRECIABLE
	Si -350mV<E_{corr}<-200mV	Incertidumbre		50-100 KΩcm	BAJA		0.1µA/cm^2<I_{corr}<0.5µA/cm^2	BAJA
				10-50 KΩcm	MODERADA*		0.5µA/cm^2<I_{corr}<1µA/cm^2	MODERADA
	Si E_{corr}<-350mV	Prob corr >90%		<10 KΩcm	ALTA**		I_{corr}>1µA/cm^2	ALTA

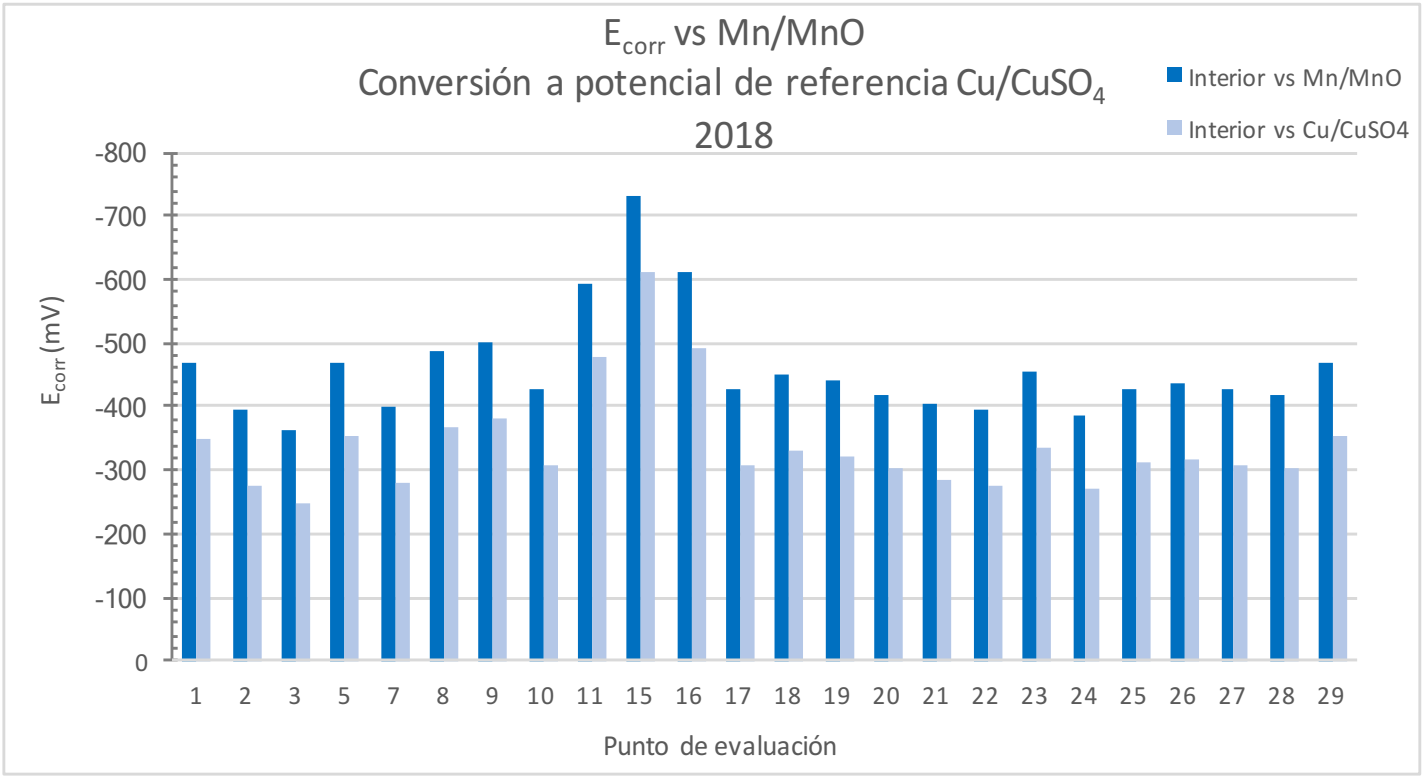
*En hormigones con Cl^- o carbonatados

**El I_{corr} obtenido será el máximo para un determinado nivel de Cl o carbonatación

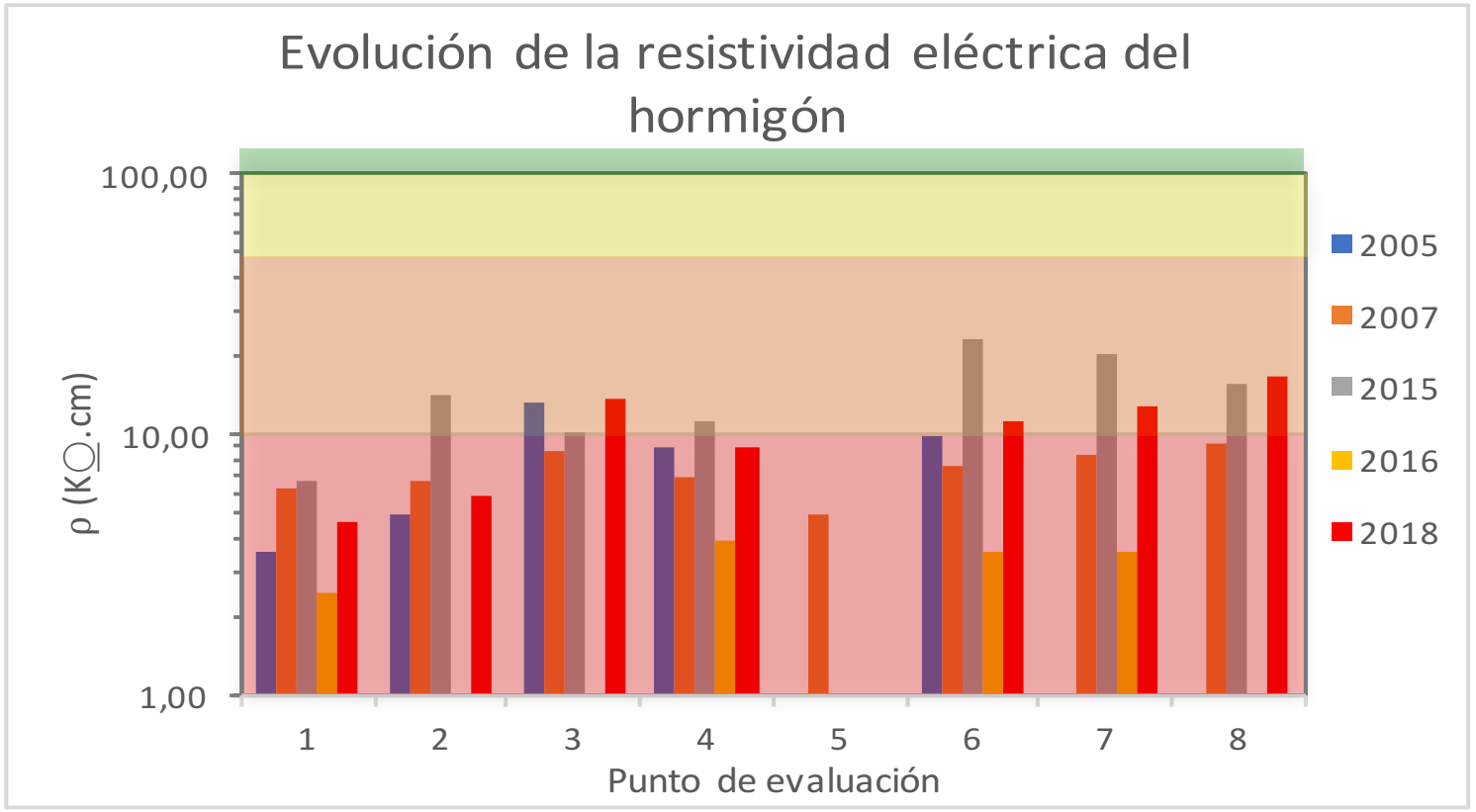
RESULTS


Evolución E_{corr} vs $Cu/CuSO_4$: Evaluación sobre la superficie de la losa
E_{corr} (mV)
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
1
2
3
4
5
6
7
8
Punto de evaluación
2005
2007
2015
2016
2018

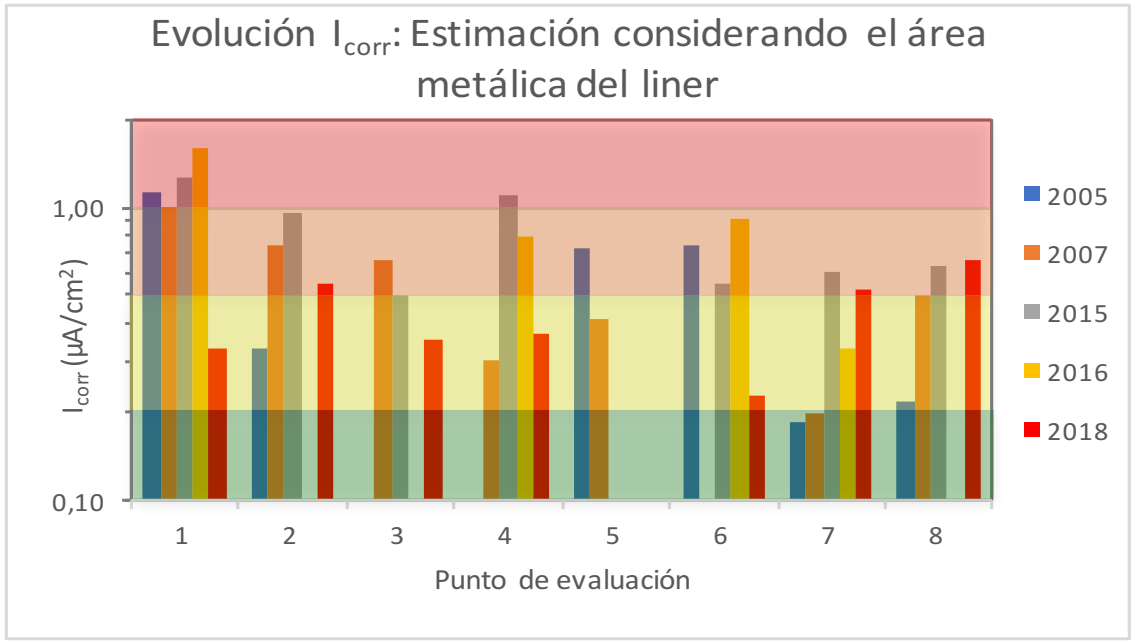
RESULTS

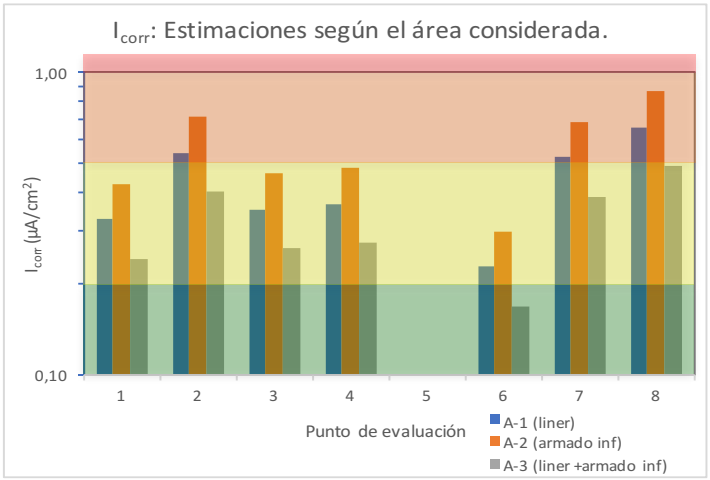

E_{corr} vs Mn/MnO
Conversión a potencial de referencia Cu/$CuSO_4$
2018
Interior vs Mn/MnO
Interior vs Cu/CuSO4
-800
-700
-600
-500
-400
-300
-200
-100
0
E_{corr} (mV)
1 2 3 5 7 8 9 10 11 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Punto de evaluación

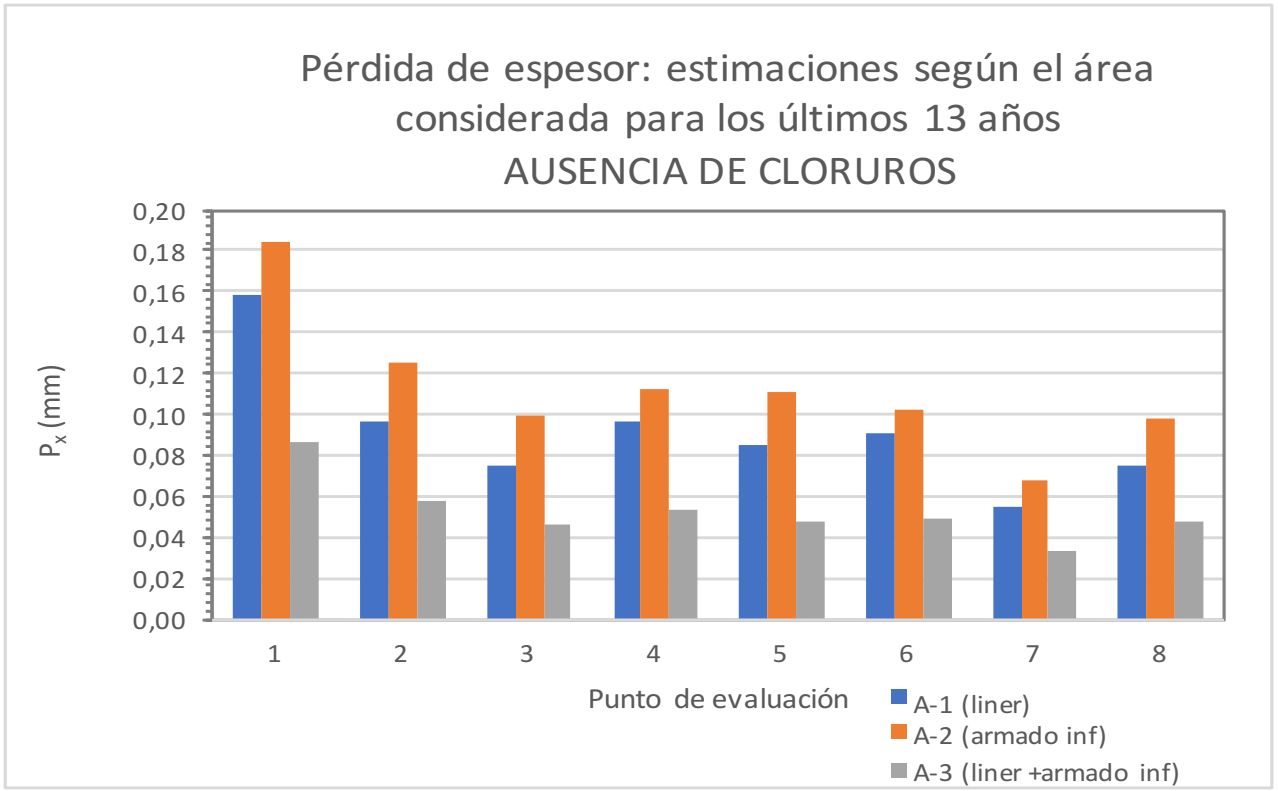
RESULTS


Evolución de la resistividad eléctrica del hormigón
100,00
10,00
1,00
ρ (KΩ.cm)
1
2
3
4
5
6
7
8
Punto de evaluación
2005
2007
2015
2016
2018

RESULTS


Evolución I_{corr}: Estimación considerando el área metálica del liner
1,00
0,10
I_{corr} (µA/cm²)
1
2
3
4
5
6
7
8
Punto de evaluación
2005
2007
2015
2016
2018

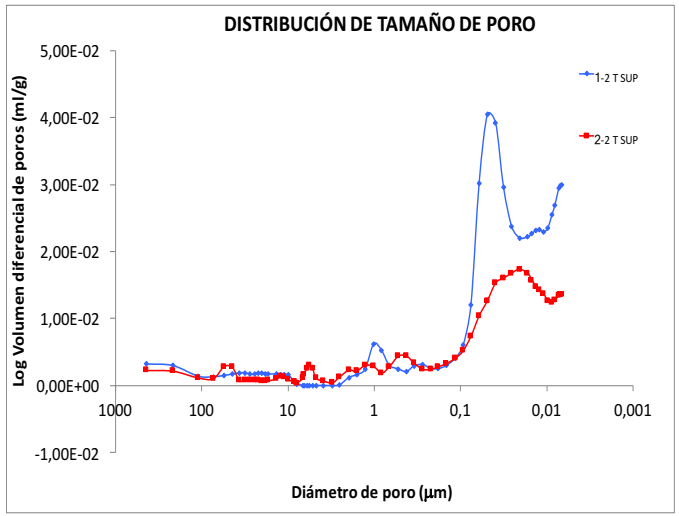

I_{corr}: Estimaciones según el área considerada.
1,00
0,10
I_{corr} (µA/cm²)
1
2
3
4
5
6
7
8
Punto de evaluación
A-1 (liner)
A-2 (armado inf)
A-3 (liner +armado inf)


Pérdida de espesor: estimaciones según el área considerada para los últimos 13 años
AUSENCIA DE CLORUROS
0,20
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
Px (mm)
1
2
3
4
5
6
7
8
Punto de evaluación
A-1 (liner)
A-2 (armado inf)
A-3 (liner +armado inf)

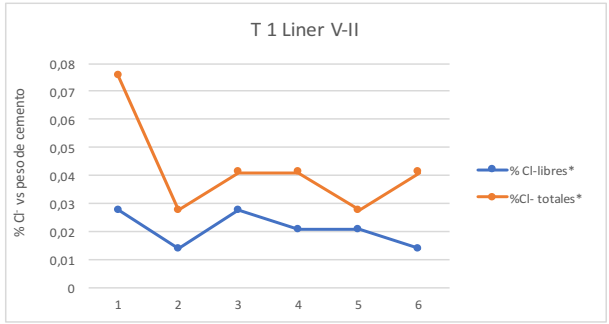
- Concrete characterization: destructive tests

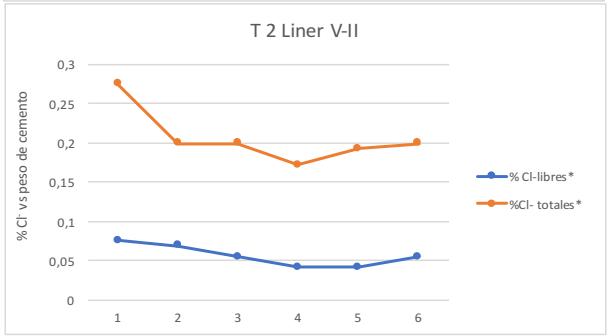


- Concrete characterization: destructive tests



MUESTRA	pH
1-2 SUP	12,021
1-2 INF	12,097
2-2 SUP	11,922
2-2 INF	11,903
PROMEDIO	**11,986**





		Valores medios	
TESTIGO	**Muestra**	**Resistividad [kΩ·cm]**	**Resistividad [Ω·m]**
T1	**1.2.T.CP**	**11,61**	**116,06**
T2	**2.1.T.R02**	**27,19**	**271,92**
T2	**2.2.T.CP**	**40,31**	**403,09**

TESTIGO	Muestra	DIMENSIONES (cm)	FUERZA (KNw)	RESISTENCIA (MPa)
T1	**1.2-T-Centro**	7,5 X 15	240,17	54,364
T2	**2.2-T-Centro**	7,5 X 15	316,42	71,623

CONCLUSIONS

In view of the results obtained in the on-site electrochemical evaluation, it can be affirmed that in this moment, the values of corrosion rate are in slight decrease with respect to that evaluated in previous years, being the zones with greater risk at this moment the zones no. 2, No. 7 and No. 8 (moderate corrosion).

Take note that the values can be affected by the presence of different metal elements embedded in the slab, such as anchor bolts or other fastening or reinforcement elements (not only reinforced or liner).

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Muchas gracias! / Thank you very much!

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